

MULTIFUNCTIONAL, TRANSPARENT PV-FAÇADE FOR THE ENERGETIC REHABILITATION OF AN OFFICE BUILDING IN BARCELONA

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ABSTRACT

The present paper shows an example for an integrated design process in the field of solar architecture, combining the design work of the architect, the use of simulation tools and the applied research on new combinations of materials like amorphous silicium, semi-transparent PV panels and coloured glass, with the aim of the energetic optimization of an architectural project.

This integrated design approach is promoted and applied by CISol- Centre for Solar Research at the School of Architecture ETSAV as a method for a sustainable building design.

1. INTRODUCTION

The presentation shows the case study of an energetic rehabilitation of a five-story staircase and the adjacent zones that suffered severe problems of overheating and cold due to an insufficient ventilation, the lack of sun shading, and an overall deficient thermal behaviour.

Industrial fixed glazing elements are substituted by an multifunctional double-glazed facade consistent of a combination of transparent PV panels and coloured and printed glass elements.

An intelligent natural ventilation strategy is developed to cope with the special condition of the staircase as intermediate space between the air-conditioned office space and the exterior.

Thermal measurements were made before and after the intervention. Simulation tools were used to define the right combination of materials in terms of sun shading, daylight use, electricity production and architectural quality.

Design, technologies and concepts were further developed and validated by design studies and measurements realized as applied research activity by CISol.

Base for this work is the concept of a Solar Network, seeing research centres like CISol in the important role as connecting elements between the different entities working in the field of architecture, solar energy and sustainability.

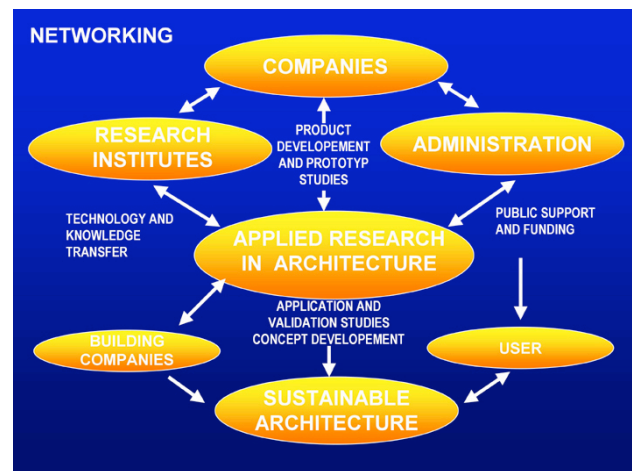


Fig. 1: Scheme for networking and applied research in solar architecture.

2. SITUATION

SCHOTT Ibèrica SA is a glass manufacturing company situated in Sant Adria del Besos, a small community beside Barcelona, within a mixed-use residential and industrial area, approximately 500m from the seaside.

The office building, constructed in 2001 is located within the fabric site, touching one of the manufacturing halls. It is northeast / southwest orientated with a totally glazed staircase on its southwest façade.

This staircase suffered a severe overheating problem in summer, due to the fixed, industrial glazing element without openings and without any shading device. Poor thermal behaviour due to thermal bridges and high U-values of the glazing created discomfort also in winter with very low temperatures inside.

3. OBJECTIVES

The overheating problem had to be solved, at the same time, as the companies own products should be applied for this purpose. In total the situations of discomfort in summer and winter had to be smoothed, as the occupants of the building to move between different offices frequently use the staircase.

4. APPROACH

The first idea for the project was to develop a corporate identity concept for SCHOTT, bringing together different of their products in new combinations, solving in an innovative way existing climatic problems and creating a piece of remarkable architecture as best reference for the company.

5. DESIGN PROCESS

In a first stage, a preliminary study was made, defining the above mentioned problems of overheating, missing sun protection, deficient natural ventilation possibilities, glare problems, thermal bridges and deficient overall thermal behaviour.

Monitoring was done by use of TESTO data loggers in 6 different points of the building, recording values of air temperature and relative humidity every 30 minutes for about 40 days in July and August and 40 days in December and January.



Fig. 2: Building analysis and description of deficiencies.

Comparing measurements by hand at different moments during the monitoring period controlled these results.

Results showed that in some parts of the staircase temperatures of about 50 ° Celsius were reached in August, and normal air temperature of the staircase in summer could easily be 10 to 15 degrees above ambient temperature.

In winter interior temperatures in the staircase in the morning were only slightly above outside temperatures.

A second step was the study of the sun situation of the façade, defining the amount of incident solar radiation throughout the year and the shading situation due to the adjacent building.

According to radiation data for Barcelona, there is a maximum amount of 1600 kWh/m2a inciting on a south orientated and 40° inclined plane.

Due to the verticality of the façade and the southwest orientation the incident radiation on the façade is reduced to approximately 67 % of this amount, which means around 1060 kWh/m2a.

A 3D modelling of the building with a sun study was realized for different moments of the year to define approximately the influence of shading on the façade and a possible photovoltaic installation.

As a result, a division line was defined, dividing the façade in two parts, one upper part, appropriate for a PV installation as receiving sun throughout the whole year, and one lower part, recommended to be realized without a PV installation, due to the shading caused by the adjacent building.

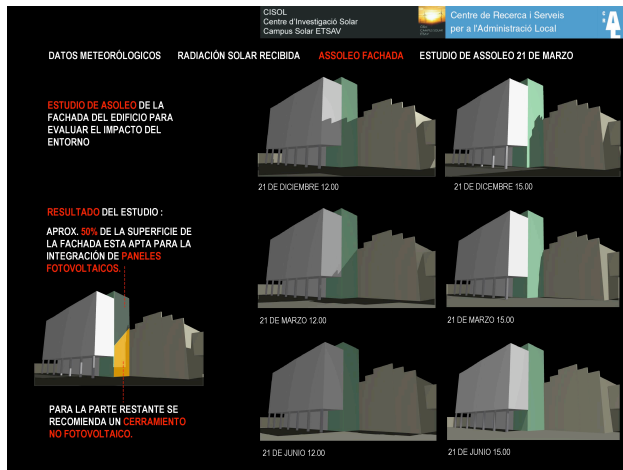


Fig. 3: Sun study and evaluation of shadowing by adjacent buildings.

In a third step this results were translated into a first design proposal with different materials in the façade.

For the upper part there was recommended the use of ASITHRU semi transparent PV panels, product of RWE SCHOTT Solar, in a double glazing element, whereas for the lower part a combination of IMERA coloured glass, product of SCHOTT AG, as double glazed element with an white screen printing as additional sun protection and design element was foreseen.

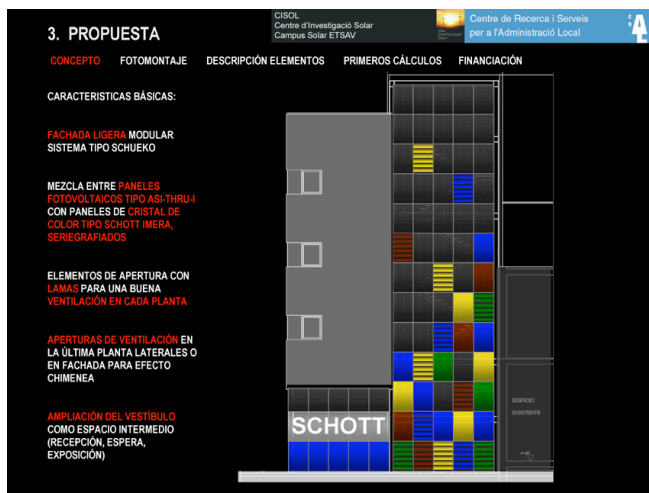


Fig. 4: First design proposal for a mixed colored glass and PV facade

For natural ventilation there were proposed glass louvers in different elements of the coloured glass façade and additional ventilation openings in the upper part, to create a chimney effect within the staircase.

An additional entrance hall was proposed as a climatic buffer space between the staircase and outside.

From the architectural point of view, this proposal created a new corporate design for SCHOTT Ibérica SA, combining there own products in their building facade like two hands reaching each other representing two (product) lines of the company coming together to form one combined element.

As final step of the design process, a combination of PV panels and coloured glass sheets was proposed to explore ones more the creative potential of the companies products.

6. PROTOTYPES

As there was so far no experience in the combination of IMERA coloured glass with ASITHRU transparent PV panels, prototypes of different colours and glass combination have been produced, to evaluate their architectural potential.

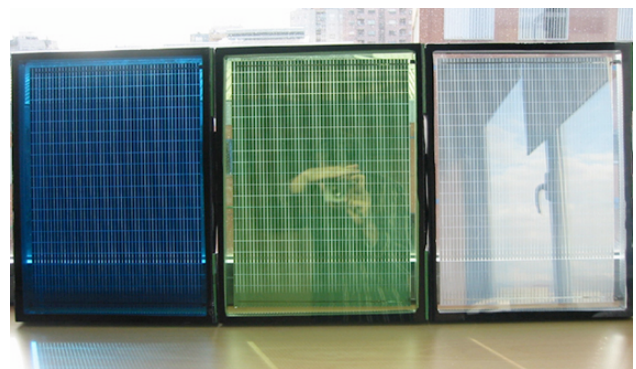


Fig. 5: Prototypes of ASITHRU PV Elements with coloured IMERA glass.

The semi-transparency of ASITHRU in combination with coloured glass showed a promising effect of light and shadow as well as from inside as from outside, by the way that sun protection could be improved a little more.

Also for the IMERA double glazed elements prototypes were produced with different kinds of screen printing, finding a compromise between the sun shading properties and design aspects in terms of the play of light and shadow, opacity and transparency.

The effect of a negative screen-printing was used, allowing to project with coloured light the printed writing on inside surfaces.

Different sizes of writings and density of printings were proved to achieve the best results in design and sun protection.



Fig. 6: Double-glazed IMERA element with screen-printing as sun protection and design feature.

7. THERMAL SIMULATION

A thermal simulation with TRNSYS was made to evaluate the effect of the proposed design on the thermal behaviour of the building and to optimize the proposed strategies in the field of sun protection and natural ventilation.

Different sizes of openings were simulated to define the requirements for sufficient natural ventilation.

The overall performance of the proposal showed to be promising. Maximum temperatures in the staircase could be dropped in summer to just 2-3° Celsius above the ambient temperature.

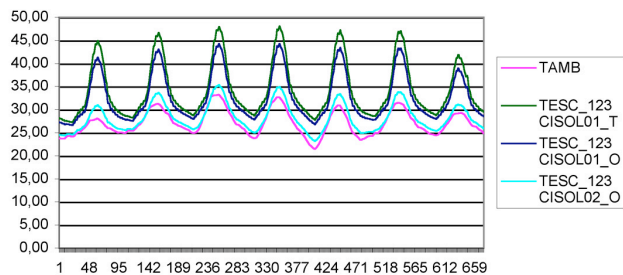


Fig. 7: Simulation results for air temperature during summer reference week before and after the intervention.

In winter maximums on the other side dropped also from about 26°Celsius to about 21° Celsius, due to the improved sun protection, which limits in winter the desired direct solar gains, but the minimum temperatures did not change.

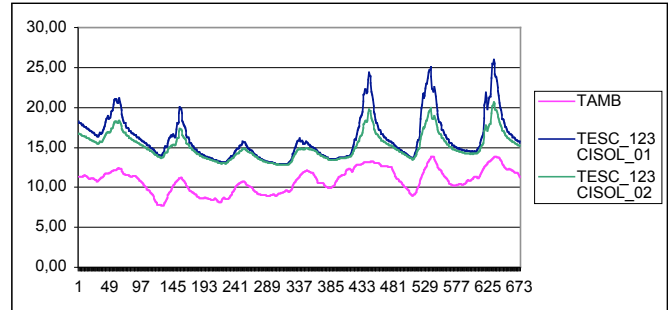


Fig. 8: Simulation results of air temperature during winter reference week before and after the intervention.

The chosen construction system, a semi-structural curtain wall façade, already conditioned the possibility of integration of openings. For design reasons there was a first decision for so called Italian windows, opening towards the outside, and in closed position almost invisibly integrated like fixed glazing elements.

This façade system showed to be a problem in terms of shadow projection on the PV panels in the upper part of the façade. Even a 15-degree opening would have caused shadow on some part of below installed ASITHRU photovoltaic elements, causing a notable loss of productivity of the whole PV installation.

So finally the decision was made to introduce a line of windows in the upper part of the façade, which open to the inside, permitting fully opened a free ventilation opening of 1,6 m2, required minimum according to the TRYNSIS simulation results.

For visual aspects, but also as a weather protection, fixed metal lamellas are used to cover these openings towards the outside, reducing only slightly the free ventilation opening. The effect of vegetation in front of the lower openings in the façade was simulated and found as little significant.

One concern for safety reasons was the temperature that could reach the semitransparent ASITHRU PV elements as well as the screen printed coloured glass panels, as they are in direct contact with the staircase.

Simulation showed that the surface temperature of PV panels would not get higher than 48° Celsius, and the temperature of coloured glass panels would be limited to a maximum of 43° Celsius.

According to simulation results, with the new facade the overall heating and cooling demand of the office building could be reduced by 8 %, dropping from about 87 kWh/m2a to approximately 80 kWh/m2a.

8. RESULTS

Results of thermal simulations have been introduced into the project, finding an architectonically attractive solution for each parameter.

The example of the Solar Façade for SCHOTT Ibèrica SA shows how this concept can be put into practice by a close and interdisciplinary collaboration between industry, research centres and university.

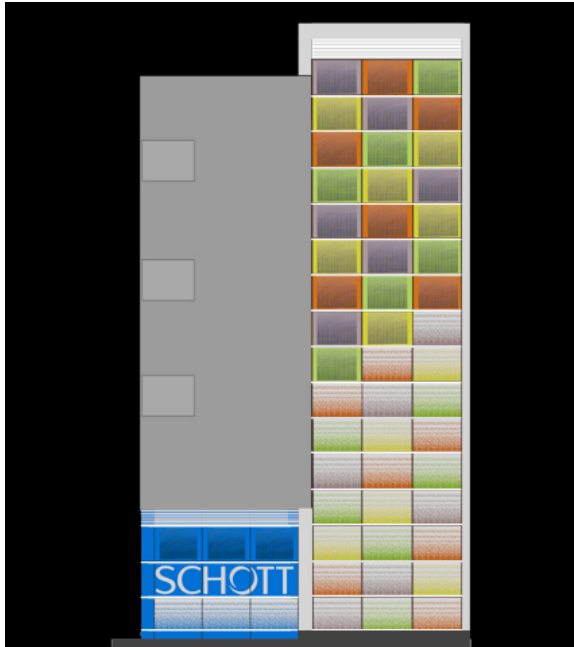


Fig. 9: Final design scheme.

The ASITHRU PV installation has a potential of about 1,5 kWp which is a rather small installation, but the project has to be understood as an integrated answer to a whole row of necessities. In this sense the PV installation contributes positively in the field of daylight use, sun protection, visual relation to the exterior, thermal behaviour of staircase and building and last but not least as a corporate identity element for the company.

The project is now under construction. Final results will be presented at the conference.

9. CONCLUSIONS

The presented project reflects the philosophy of the integrated design approach, which the CISol- Centre for Solar Research ETSAV, tries to implement into the architectural education at the Polytechnic University of Catalonia (UPC) but also in its work as a service and research centre, offering services in the fields of energy consultancy, technological education, solar design and applied research on new solar building elements to public and private entities.